**Rad 160 - Radiographic Physics**

**Unit 3 Electrodynamics**

I. Electrodynamics – electric charges in motion.

A. Also called electric current.

B. Measured in amperes – the number of electric charges flowing in the electric current.

II. Electric Current – consists of a flow of charged particles that can be controlled and is useful.

A. Example – electricity that lights homes and powers tv’s.

B. Charged particles are – positively charged ions, negatively charged ions or electrons.

Electric charges do not just flow on their own; certain circumstances must exist for them to move.

C. Conditions under which electric charges (e-‘s) can flow:

1. In a vacuum – electrons may jump a gap between two oppositely charged electrodes. (Remember electrons are charged particles.)

Ex. In an x-ray tube electrons jump from the cathode (-) to the anode (+).

Electrode – an electrical terminal that carries a particular charge: either positive like an anode or negative like a cathode.

2. In a gas – two oppositely charged electrodes placed in a gas will cause the positive ions in the gas to drift toward the negative electrode (cathode) and the negative ions to drift to the positive electrode (anode).

Ex. A neon tube

3. In an ionic solution – ions of different charges immersed in a solution will move toward electrodes of opposite charges also immersed in the solution.

Ex. Dissolve NaCl in water. It separates into Na+ and Cl- ions. The Na+ ions move to the cathode and the Cl- ions move to the anode.

4. In a metallic conductor – a wire made up of copper, aluminum, etc. allows a free flow of charged particles. This is the one will we will be most interested in.

a. Most common pathway for electric current.

b. The charged particles that move in a metallic conductor are electrons.

c. To make electrons flow through the conductor there must be an excess of electrons at one end & a deficiency at the other.

\* Electrons move from higher negativity to lower negativity.

III. Electric Circuit – the path over which current flows. Electrons do not flow in non- conductors & only in semiconductors under certain conditions.

A. What causes electrons to move in a metallic conductor?

\* Sources pile up electrons at one end of a conductor & simultaneously remove them from the other end. This keeps electrons flowing.

B. Sources of electric current

1. Battery or cells – convert chemical energy to electric energy.

a. Types of Batteries:

i. Dry Cell - like a “D” battery

\* flashlight

ii. Wet Cell – like a car battery

\* a car battery has several cells in it

2. Generator or dynamo – convert mechanical energy to electrical energy by electromagnetic induction.

3. Solar cells – sunlight to make energy

4. Wind – windmills

5. Atomic – nuclear energy

C. Characteristics of an Electric Circuit

1. Potential Difference – a difference in electrical potential energy between 2 points in an electric circuit. The difference of potential that drives the electrons. Difference in amount of electricity between point A to point B. Flows from area of greater energy to lesser energy.

a. electromotive force (EMF) – applies to the maximum difference of potential between the terminals of a battery or generator.

b. unit = volt – potential difference which will cause a current of 1 ampere to flow in a circuit whose resistance is 1 ohm.

c. potential difference = EMF = voltage

2. Current – amount of electric charge (electrons) flowing through a conductor per second.

a. The more electrons flowing, the stronger the current.

b. unit = ampere – 1 coulomb quantity of electric charge flowing per second.

c. Current flows from (-) to (+).

3. Resistance – property of the circuit which opposes or hinders the flow of an electric current.

a. unit = ohm – (Ω) resistance of a standard volume of mercury under standard conditions.

b. depends upon:

i. material – conductors, semiconductors, insulators

ii. length – resistance is directly proportional to the length of the conductor. A long wire has more R than a short wire.

iii. cross-sectional area – resistance is inversely proportional to the cross-sectional area. A wire with a large cross-sectional area has less R than a small cross-sectional wire.

iv. temperature of the conductor - the higher the temperature, the higher the resistance.

v. electric consuming devices added to the circuit – the more devices added, the greater the hindrance to the flow.

Ex. Light bulb, toaster, blender, etc.

D. Ohm’s Law

1. Definition – the current in a metallic circuit equals the potential difference divided by the resistance.

I = V/R I = current in amps

V = potential difference in volts

R = resistance in ohms

or V = I X R or R = V/I

2. Relationships

a. The current in a circuit is directly proportional to the voltage applied.

Ex. By ↑ volts, ↑ current & ↓ volts will ↓ current

b. Current is inversely proportional to the resistance.

Ex. ↓ resistance will ↑ current & ↑ resistance will ↓ current

Ex. A current of 0.5 amps is flowing through a conductor with a resistance of 14 ohms. What is the voltage between the ends of the conductor?

Ex. What is the resistance in a circuit of 150V & 30 amps?

IV. Components of a Simple Electric Circuit

A. Simple Electric Circuit – The electrons are always flowing the same direction.

DC = direct current

B. Essential Parts:

1. Power source – something supplying a potential difference.

Ex. Battery or generator

2. Conductor – the pathway for electrons to flow.

Ex. A metallic wire

3. Resistance – hindrance of flow

Ex. A light bulb, toaster, tv

4. Switch – opens or closes the circuit. Current flows only when the switch is closed.

Ex. When the switch is open, the circuit is open and current will not flow.

When the switch is closed, the circuit is closed and current will flow.

C. Polarity – the direction a current in a circuit flows when supplied by a battery. It flows from the cathode (-) , through the circuit, to the anode (+).

V. Two Basic Types of Circuits

A. Series Circuit – an electric circuit whose resistors are arranged one after the other in a line so that the current passes consecutively through each as it moves along the conductor.

B. Three Rules of a Series Circuit

1. Total circuit resistance = the sum of the individual resistances.

Rtotal = R1+R2+R3

2. Total circuit current = current through each circuit element is the same & is equal to the total circuit current.

Itotal = I1=I2=I3

3. Total circuit voltage = the sum of the voltages across each resistor

Vtotal = V1+V2+V3

Example:

What is the total resistance?

What is the circuit current?

What is the voltage across the entire circuit?

C. Parallel Circuit – An electric circuit whose resistors are connected as branches of the main circuit so that the current is divided among them.

D. Three Rules of a Parallel Circuit

1. Total circuit current = the sum of the currents through each resistor.

Itotal = I1+I2+I3

2. Total circuit voltage = the voltage across each of the circuits component parts.

Vtotal = V1=V2=V3

3. Total circuit resistance is inversely proportional to the sum of the reciprocals of each individual resistance.

1/Rtotal = 1/R1 + 1/R2 + 1/R3

Example:

What is the total resistance of the circuit?

What is the total circuit current?

E. Advantages of a Parallel Circuit

1. The current is divided among the circuit branches and the smallest current flows in the branch having the greatest resistance.

2. Parallel circuit is used in the wiring of most homes and commercial buildings:

a. Unlike a series circuit, failure of one component of a parallel circuit does not prevent the operation of the others because they are on branches of the main circuit.

b. As more branches are added, the total resistance decreases.

c. As more branches are added, the total amperage increases.

d. As more branches are added, voltage remains unchanged.

F. Circuit Overload – when too many branches are added to a circuit and the amperage in the main circuit becomes excessive. Could result in a fire because wiring system is too hot.

Ex. Plug in too many appliances into one circuit (each appliance will have its own branch) and a fire starts or the appliance blows.

G. How to Protect the Circuit from Overload: (too much amperage)

1. Fuse – connected in the circuit and when amperage becomes too high, a wire in the fuse will melt and the circuit will be opened before any damage to the circuit or its components occurs.

2. Circuit breaker – trips a switch (opens it) if amperage becomes excessive.

H. Advantages of a Series Circuit

1. Current is constant throughout the circuit.

Itotal = I1=I2=I3

I. Disadvantages of a Series Circuit

1. If one component fails causing an open circuit, none of the components work.

VI. Electric Measuring Devices

A. Voltmeter –

1. Measures potential difference between any 2 points in a circuit (often referred to as “voltage drop”).

2. Measures this difference in volts.

3. Always connected in parallel – placed in a small circuit which is a branch of the main circuit.

B. Ammeter –

1. Measures the quantity of electric charge flowing per second.

2. Measured in amperes.

3. Will always read the same no matter where it is placed in a series circuit.

4. Connected in series – directly in the circuit.

VII. Electric Capacitor – a storage place for electricity.

A. Has pair of flat metallic plates arranged parallel to each other & separated by a small space containing air or special insulating material.

B. Many portable x-ray units function by capacitor discharge. Plug in the portable to charge the capacitor. The capacitor discharges when making an exposure.

C. Capacitance – the quantity of electric charge a capacitor can store.

VIII. Electric Power

A. Definition – the rate of doing work. Electric energy expended per second.

B. Power = amperage x voltage P = IV Power Rule

C. Unit = watts

IX. Power Loss

A. Electric energy is capable of doing work and can be converted into work and heat.

B. Heat can be considered a “power loss” in a circuit (not all the electric is converted to work, some is lost as heat).

C. Power loss = current2 x resistance P = I2 R

D. Increase resistance, increase power loss

Increase current, increase power loss

**Sample Problems Ohm’s Law**

1. A circuit carrying a current of 30 amps has a resistance of 4 ohms. Find the voltage across the circuit?

2. Find the resistance of a circuit when the current is 12 amps and the potential difference is 240 volts?

3. What is the resistance in a circuit of 140 volts and 20 amps?

4. A current of .5 amps is flowing through a conductor with a resistance of 18 ohms. What is the voltage between the ends of the conductor?

**Objectives**

1. Define electrodynamics.

2. Explain the conditions under which electric charges can flow.

3. Identify sources of electric current.

4. Describe characteristics of an electric current.

5. Solve problems using Ohm’s Law.

6. Identify the components of simple electrical circuits.

7. Define a voltmeter and ammeter.

8. Describe both series and parallel circuits.

9. Describe electric capacitors and their function.

10. Discuss power of a direct current.

**Readings**

Selman Chapter 6 & Bushong p. 65-69.

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